

Exhibit 9



ENGINEERING DATA

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Understanding Fan Curves

Introduction

This document contains introductory material designed to familiarize the user with the conventions and terminology related to fan curves. Various axial and centrifugal fan performance curves will be illustrated throughout this article with no attempt made to rationalize any particular selection. For a more in-depth look into the characteristics of different fan types, refer to ED-2300 for axial fans and ED-2400 for centrifugal fans.

Pressure Volume Curve

The most important characteristic of a fan or a system is the relationship that links the primary variables associated with its operation. The most commonly used fan characteristic is the relationship between pressure rise and volume flow rate for a constant impeller speed (RPM). Similarly the relationship between pressure loss and volume flow rate is the most commonly used system characteristic.

Fan pressure rise characteristics are normally expressed in either total pressure (TP) or static pressure (SP), with static pressure being the units most commonly used in the United States. The fan volume flow rate (airflow) is commonly expressed in cubic feet per minute, or CFM. Therefore, the system pressure loss and volume flow rate requirements are typically expressed as a certain value of static pressure (SP) at some CFM.

The fan "pressure-volume" curve is generated by connecting the fan to a laboratory test chamber. By following very specific test procedures as outlined in the Air Movement and Control Association (AMCA) Standard 210, data points are collected and plotted graphically for a constant RPM, from a "no flow" block off condition to a "full flow" or wide condition. Figure 1 represents such a curve that is typical for a vaneaxial fan, and is commonly referred to as a "static pressure" curve.

Point A represents the point of zero airflow on the static pressure curve. It is frequently referred to as "block off," "shut off," "no flow," and "static no delivery."

Point B depicts the stall region of the static pressure curve. Operation in this area is discouraged because of erratic airflow that generates excessive noise and vibration. For a more in-depth look into this phenomenon refer to ED-600, "Surge, Stall & Instabilities in Fans."

Point C depicts what is referred to as the peak of the static pressure curve, and point D is the point of maximum airflow. Point D is also referred to as "free delivery," "free air," "wide open performance," and "wide open volume."

Curve segment CD is often referred to as the right side of the fan curve. This is the stable portion of the fan curve and is where the fan is selected to operate. It then follows that curve segment AC is the left side of the fan curve and is considered to be the unstable portion of the curve.

Figure 1 is a vaneaxial curve with a pronounced dip (stall region) that is also a typical curve shape for high angle propeller fans and forward curve centrifugal fans. In contrast, compare this curve to Figure 2, which represents a typical

Figure 1. Static Pressure Curve, Vaneaxial

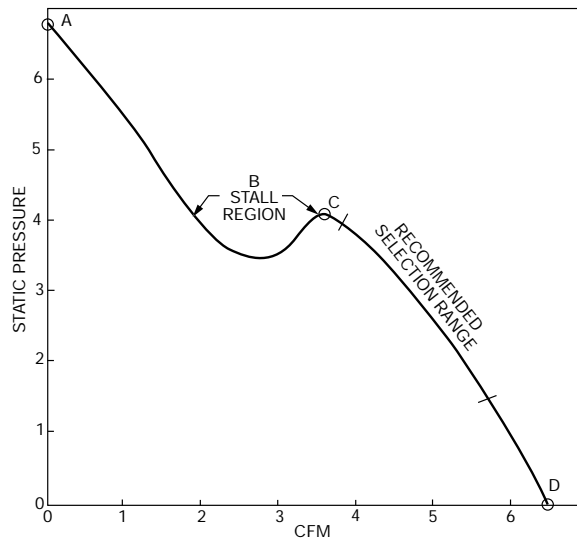
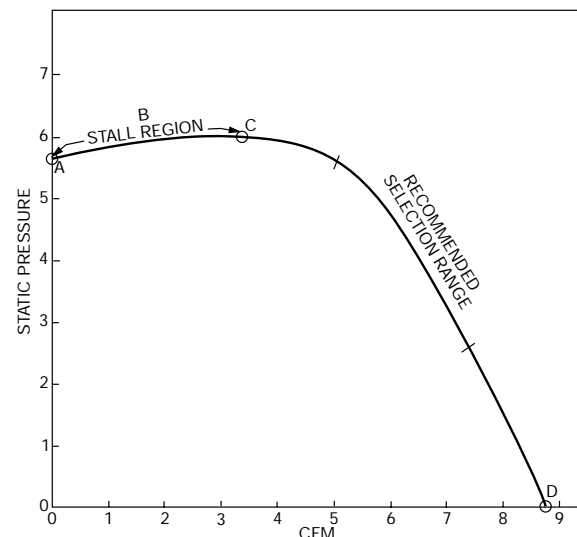


Figure 2. Static Pressure Curve, Backward Inclined Centrifugal

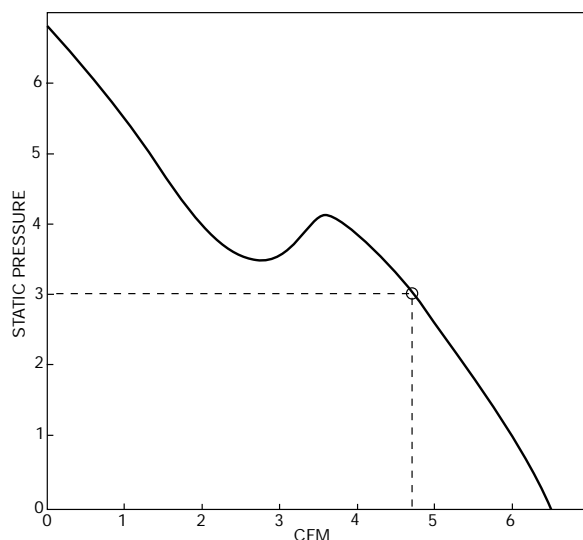


curve for a backward inclined centrifugal fan. This curve shape is also representative of radial blade centrifugal fans.

Note the lack of a pronounced dip on this curve. Nevertheless, the area left of peak is also a stall region and selections in this area should be avoided.

The fan static pressure curve is the basis for all airflow and pressure calculations. For a given SP on the static pressure curve there is a corresponding CFM at a given RPM (see Figure 3).

Figure 3. Static Pressure Curve, Vaneaxial

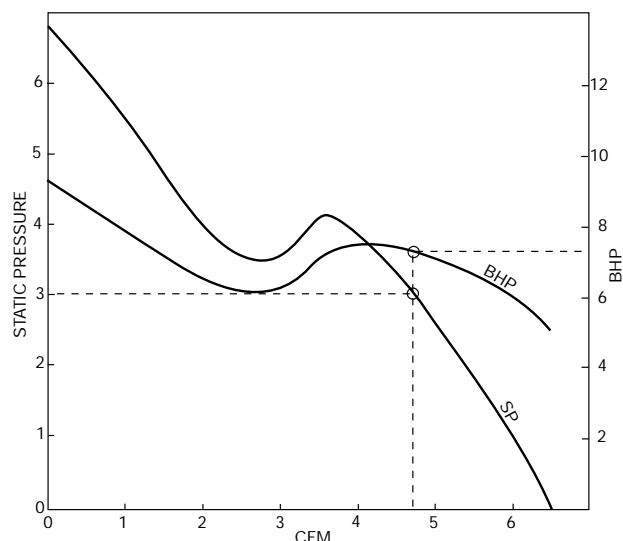


Simply locate some unit of pressure on the left hand SP scale and project a horizontal line to the point of intersection on the static pressure curve. From the point of intersection project a vertical line to the bottom CFM scale to establish the corresponding airflow at that particular speed. In this example a static pressure of three units results in a CFM of 4.71 units.

Brake Horsepower Curve

Having established a static pressure (SP) and an airflow (CFM), an operating brake horsepower (BHP) can be established (Figure 4).

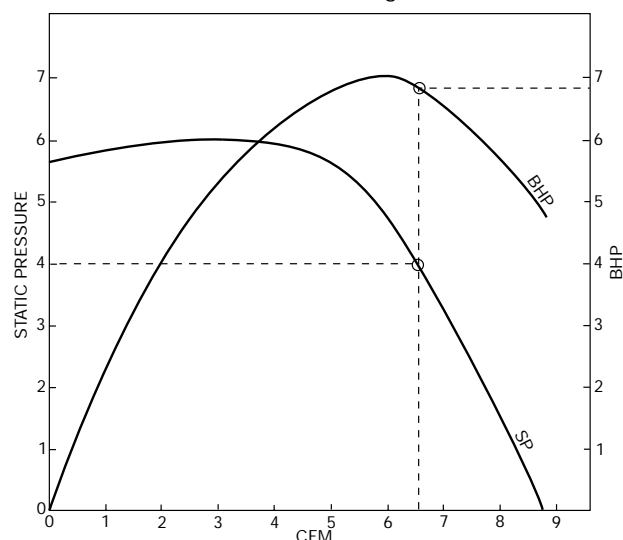
Figure 4. Static Pressure/Horsepower Curve, Vaneaxial



By adding the BHP curve to the static pressure curve from Figure 3 we complete the fan performance curve. To determine BHP simply extend vertically the CFM point established in Figure 3 until it intersects the BHP curve. Draw a horizontal line from this point of intersection to the right to the BHP scale to establish a BHP of 7.27 units, which corresponds to the previously established performance of 4.71 CFM units at 3.0 SP units.

Similarly, we can add the BHP curve to the static pressure curve of the backward inclined centrifugal fan from Figure 2 to complete that fan performance curve (Figure 5).

Figure 5. Static Pressure/Horsepower Curve Backward Inclined Centrifugal



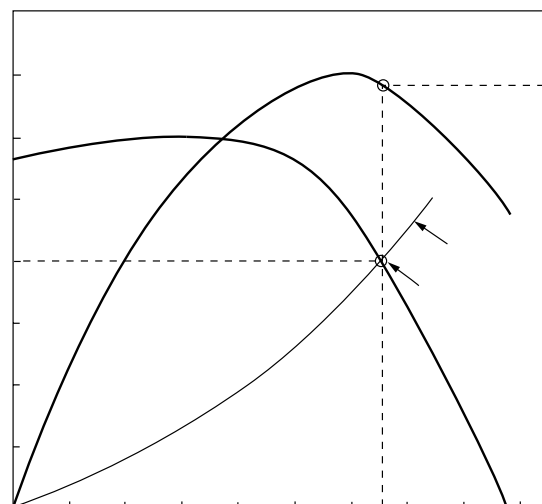
Even though the performance curves for the vaneaxial fan and the centrifugal fan have completely different shapes, the curves are read in the same way. Locate some unit of pressure on the left hand SP scale (4 units) and project a horizontal line to the point of intersection with the SP curve. Projecting downward from this point of intersection to the CFM scale we establish an airflow of 6.55 units. Now project vertically upward to intersect the BHP curve. Project a horizontal line from this point to the BHP scale and read a BHP of 6.86 units.

Operating Point

The operating point (point of operation or design point) is defined as the fan pressure rise (SP)/volumetric flow rate (CFM) condition where the fan and system are in a stable equilibrium. This corresponds to the condition at which the fan SP/CFM characteristic intersects the system pressure loss/flow rate characteristics.

Figure 6 illustrates this fan/system operating point using the centrifugal fan performance curve from Figure 5.

Figure 6. Fan/System Operating Point, Backward Inclined Centrifugal



The system line is simply a parabolic curve made up of all possible SP and CFM combinations within a given system and is determined from the fan law that SP varies as RPM^2 . Another fan law states that CFM varies as the RPM. Therefore, we can also say that SP varies as CFM^2 . Note: Some systems have modulating dampers which will not follow this parabolic curve.

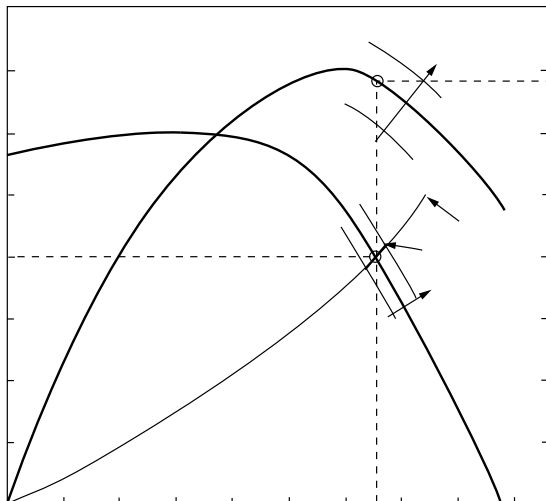
Sometimes a fan system does not operate properly according to the design conditions. The measured airflow in the fan system may be deficient or it may be delivering too much CFM. In either case, it is necessary to either speed the fan up or slow it down to attain design conditions.

Knowing that the fan must operate somewhere along the system curve, and knowing that it is possible to predict the fan performance at other speeds by applying the following fan laws:

1. CFM varies as RPM
2. SP varies as RPM^2
3. BHP varies as RPM^3

We can now graphically present an "operating line" between various fan speeds using the fan/system operating point data from Figure 6. This results in new SP curves and BHP curves as shown in Figure 7.

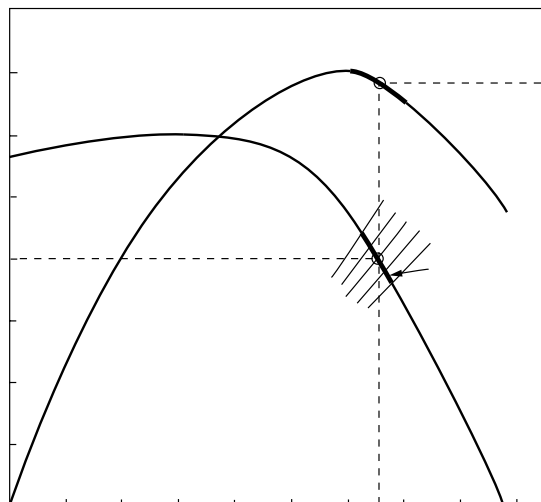
Figure 7. Variable Fan Characteristic Curve, Backward Inclined Centrifugal



These speed changes represent an example of fan control that can be accomplished through drive changes or a variable speed motor.

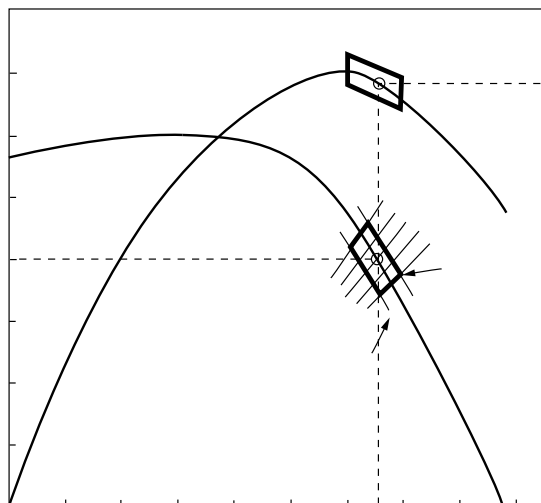
Another way to present an "operating line" is to add a damper, making the system the variable characteristic. By modulating the damper blades, new system lines are created resulting in an operating line along the fan curve. This can be seen graphically in Figure 8.

Figure 8. Variable System Characteristic Curve, Backward Inclined Centrifugal



Combining the fan control curve (Figure 7) with the system controlled curve (Figure 8) results in a fan/system controlled curve having an "operating region" as shown in Figure 9.

Figure 9. Variable Fan/System Characteristic Curve Backward Inclined Centrifugal



Conclusion

The foregoing methodology provides the knowledge necessary to understand fan curves. When used in conjunction with ED-100, ED-600, ED-2300 and ED-2400, it provides the user with the working knowledge necessary to understand the fan performance characteristics and capabilities of different fan equipment.



Twin City Fan Companies, Ltd.

Designers & Manufacturers of Air Moving Equipment

5959 Trenton Lane · Minneapolis, MN 55442-3238
Phone (763) 551-7600 · Fax (763) 551-7601 · www.twincityfan.com

